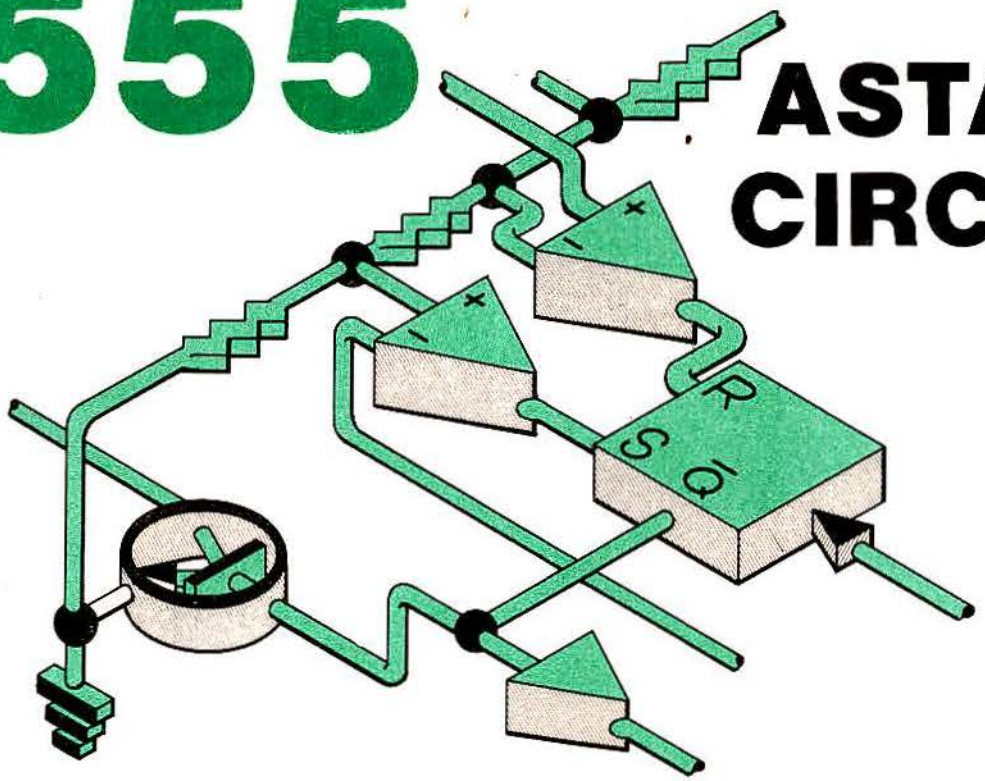
555 ASTABLE CIRCUITS



We explore how to use the popular 555 timer IC in practical oscillator applications.

BY RAY MARSTON

One of the most celebrated chips on the market is the 555 timer. Its simplicity and versatility have secured its success in industrial and hobbyist applications. Let's take a look at the 555 and discuss how to use it in practical astable (oscillator) circuits.

555 Astable Basics. The 555 timer IC can be easily used as the basis for an astable multivibrator or square-wave generator. Figure 1 shows a block diagram of the IC and the external connections needed to make it act in that manner. Note that the trigger input (pin 2) is shorted to the threshold terminal (pin 6), and that timing resistor R2 is wired between pin 6 and pin 7 (the discharge terminal).

When power is initially applied to this circuit, C1 is initially uncharged, so the IC's trigger input is low, which sets the output (pin 3) high and simultaneously switches Q1 off. Under this condition, C1 starts to charge exponentially towards the supply-rail voltage (V_{cc}) via R1 and R2. Eventually the voltage across C1 rises to ⅔'s of V_{cc}, at which point the IC's built-in threshold-voltage comparator activates and changes the state of the internal flip-flop, causing the pin 3 output to go low and Q1 to turn on.

That completes the astable's power-up cycle; all subsequent cycles may be regarded as oscillations, which occur as follows: As Q1 turns on at the end of the power-on cycle, it pulls discharge pin 7 low and starts to exponentially discharge C1 via R2 until the voltage across C1 falls to ⅓ of V_{cc}, at which point the trigger-voltage comparator toggles the internal flip-flop. That turns Q1 off again, causing C1 to charge exponentially via R1 and R2 until the voltage across C1 again rises to ⅔'s of V_{cc}, at which point Q1 turns on again, etc. This timing sequence then repeats *ad infinitum*, with C1 alternately charging via R1 and R2, and discharging via R2.

Regarding the circuit's actual timing, the period of the initial power-up pulse is:

$$1.1(R1 + R2)C1$$

but on all subsequent cycles the high period (t1) will be:

$$t1 = 0.7(R1 + R2)C1$$

and the low period (t2) will be:

$$t2 = 0.7R2C1$$

Note that (ignoring the power-up cycle) if R2 is very large relative to R1, the operating frequency is more or less set by R2 and C1. Also, the output will be an almost symmetrical square-wave and a near-linear triangle wave will appear across C1.

Figure 2 shows a practical version of the basic astable circuit together with its waveforms (after the power-up cycle). By the way, C2 is used to enhance the stability of the circuit which, with the component values shown, operates at about 1 kHz.

In practice, the values of R1 and R2 can be varied from 1k to several megohms; however, note that R1 greatly affects the circuit's current consumption since it is grounded via pin 7 during a portion of each cycle. Also note that the waveform's duty cycle can be tailored for an application by choosing suitable values for R1 and R2.

The circuit in Fig. 2 can be made more versatile by replacing R2 with a 10k resistor and a 100k potentiometer wired in series. Then the potentiometer can be used to vary the frequency from 650 Hz to 7.2 kHz. The frequency span can be further increased by selecting alternative values of C1 (perhaps via a multipole switch); the frequency range can be reduced by a decade by increasing C1's value by a factor of ten, and vice versa.

Duty-Cycle Control. As mentioned

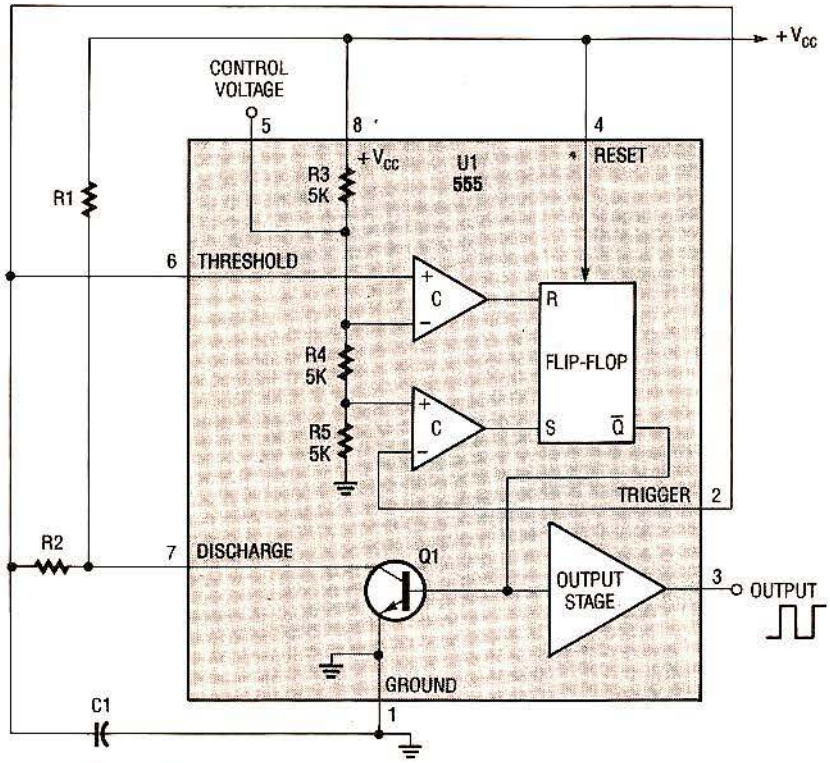


Fig. 1. This is a block diagram of the 555 IC, together with the external components necessary to use it as an astable multivibrator.

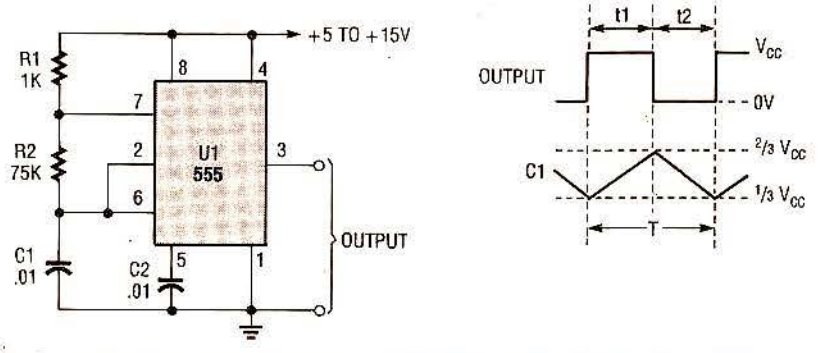


Fig. 2. This basic 1-kHz 555 astable multivibrator is free-running; once power is applied, it will oscillate.

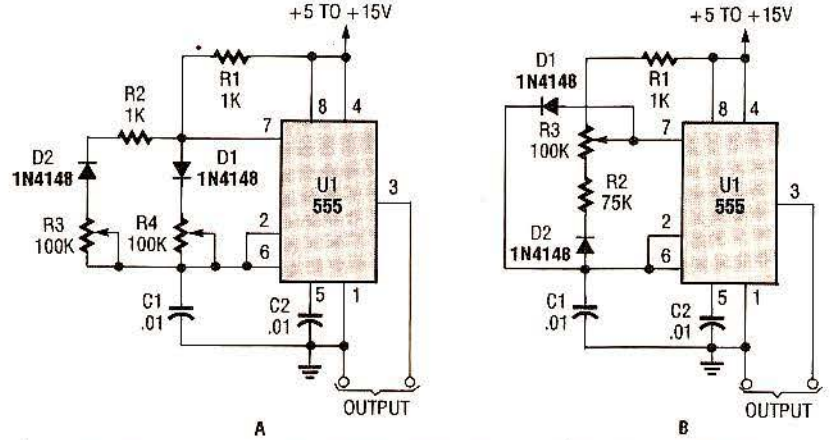


Fig. 3. The oscillator in A has been configured so its high and low periods are independently variable from 7 µs to 750 µs. The one in B is a 1.2-kHz unit with a duty cycle variable from 1% to 99%.

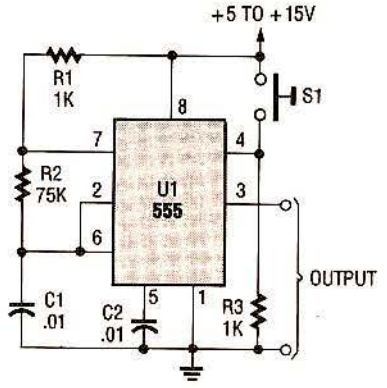


Fig. 4. This gated 1-kHz astable multivibrator permits press-to-turn-on operation.

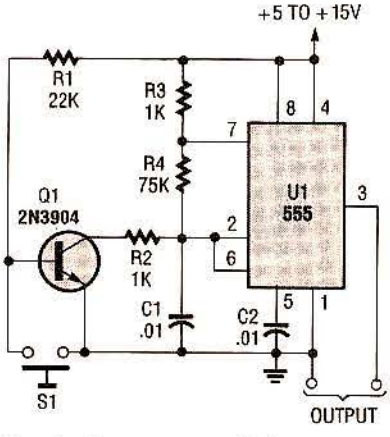


Fig. 5. Alternative gated 1-kHz astable with 'press-to turn-on' operation.

earlier the duty cycle of the circuit in Fig. 1 depends on the values of R1 and R2. Figures 3A and 3B show practical ways of making the duty cycle fully variable with the aid of steering diodes that automatically select alternate charge and discharge paths for C1.

The Fig. 3A circuit gives independent control of both the high and low periods. There, C1 charges via R1, R4, and D1, and discharges via R2, R3, and D2. The potentiometer values shown allow the high and low periods to to be varied over a 100:1 range (from 7 µs to 750 µs). Keep in mind that the output frequency must vary as the high or low times are altered.

Figure 3B shows a way of altering the M/S ratio without significantly altering the circuit's operating frequency. There, the high period increases as the low period decreases, and vice versa, so the total period of each cycle (and thus the frequency) is constant. The most important feature of

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the circuit is that its duty cycle is fully variable from 1% to 99% via R3. In the circuit, C1 alternately charges via R1, D1, and the upper half of R3, and discharges via D2, R2, and the lower half of R3 With the component values shown, the circuit operates at about 1.2 kHz.

Astable Gating. A 555-based oscillator can be gated on and off, via either a switch or an electronic signal, in several different ways. One way is by using the reset (pin 4) terminal as shown in Fig. 4. To enable a 555, its reset pin (pin 4) must be biased above 0.7 volts, but is disabled (with its output low) if pin 4 is pulled below 0.7 volts by a current greater than 0.1 mA (*i.e.*, by grounding pin 4 via a path with a resistance of 7k or less). Thus, the circuit in Fig. 4 is normally gated off by R3 but can be turned on by closing S1.

As mentioned, such an oscillator can also be gated by a circuit attached to pin 4 instead of the simple pushbutton. For example, in Fig. 5 Q1 is normally biased on via R1 and thus acts like a closed switch that (via R2) pulls the C1/R4 junction low and keeps the astable from operating; but when S1 is closed, Q1 is turned off and the astable operates in the normal way. Note that the output terminal is high when the astable is off.

FM and PPM. All the 555 astable circuits shown so far can be subjected to frequency modulation (FM) or to pulse-position modulation (PPM) by simply feeding a modulating signal to pin 5, which is connected to the IC's internal voltage-divider network. The modulating signal may be any AC or DC signal. The voltage at pin 5 influences the oscillator's high time but not the low part of each cycle, and thus provides both PPM and FM actions. These types of modulation are useful in special waveform-generator applications, as in various electronic siren and alarm-call generator circuits.

555 Sirens and Alarms. One very popular application of the 555 chip is as a speaker-driving siren or alarm-call generator. Figure 6 shows two circuits that generate pulsed-tone or warble-tone sounds, each using a pair of 555's. Both circuits have a power-boosting output stage (Q1) that provides several watts to the external speaker; clamping diodes are used to limit the speaker's inductive kickback to a safe level. To prevent the output signal from feeding back into the 555's via the supply line, the supply lines are filtered by a capacitor and an isolating diode (C5 and D2 in Fig. 6A).

The circuit acts as a pulsed-tone alarm-call generator. Integrated circuit U1 acts as an 800-Hz tone generator, and is gated on and off once per second by U2 via D1.

The Fig. 6B circuit acts as a warbling alarm-call generator that simulates the "dee-dah-dee-dah" sound of an old-style British police siren. In the circuit, U1 is again wired as a tone generator and U2 as a 1-Hz astable multivibrator, but in this case U2's output is used to frequency-modulate U1 via R5, the action being such that U1's frequency alternates between 440 and 550 Hz at a 1-Hz rate. ■

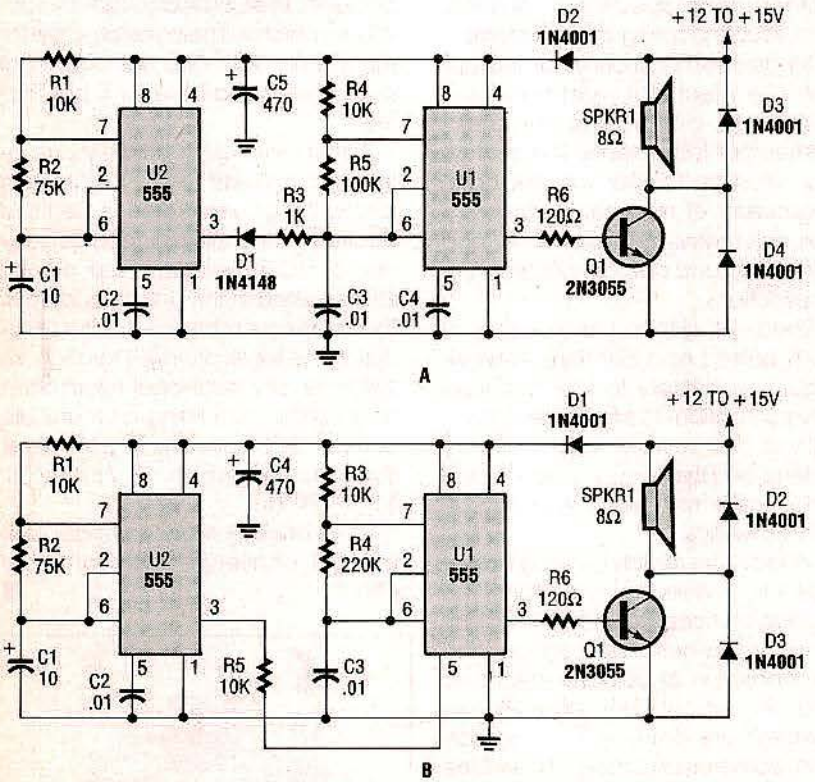

Fig. 6. The pulsed-tone alarm-call generator in A is much more intrusive than a continuous-tone unit. The sound of the warble-tone alarm-call generator in B is even more noticeable as it simulates a British police-car siren.

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